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Assessing the Impacts of Changing Public Service Provision on Geographical Accessibility: an examination of public library provision in Pembrokeshire, South Wales

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Abstract

Public libraries make an important contribution to the wellbeing of local people often acting as community hubs by reducing the isolation felt by vulnerable members of society through promoting social interaction and supporting the wider needs of local communities. However access to libraries is threatened in Wales, as elsewhere in the UK, by uncertainty stemming from changes in local government service delivery models, austerity-driven cuts in public spending, changing demands on the service from the public and the potential impacts of new developments in digital services and technologies. Drawing on network-based analysis of changes to library services in a predominantly rural authority in South-West Wales, the aim of this paper is to demonstrate how Geographical Information Systems (GIS) can be used to monitor the impacts of alternative models of provision currently being considered by library authorities. By examining the spatial impacts of changes in services following a period of re-configuration in this library authority, we point the way to methods that enable levels of provision that meet community needs to be sought during times of budgetary pressures and proposed changes to the delivery of public services.

Keywords: Public service provision; Library Service Delivery; Geographical Information Systems (GIS); Accessibility Models; Spatial inequalities.

1. Introduction

The most recently published statistics on public library usage in Wales show there were over 13.6 million visits made to those public library service points that are open for 10 hours or more a week, and over three million virtual visits to library websites in 2014-15 (Welsh Government, 2016a). In addition, as of October 2014, 1.9 million hours of PC and Internet use was recorded over 2800 terminals with free access in Welsh public libraries (Chartered Institute of Public Finance and Accountancy (Cipfa), 2014). At the same time, there has been a decline in the number of public libraries in the UK, as revealed by Cipfa in its most recent annual survey of libraries in 2015 (Cipfa, 2015), of 2.6% (from 4023 to 3917). Such trends also have to be considered within the context of debates in the UK surrounding the wider delivery of public services following austerity-driven cuts in public spending, changing demands from the public and the potential impacts of new developments in digital services and technologies. A report by the Equality and Local Government Committee of the National Assembly for Wales (2014) has drawn attention to the community role played by public libraries in addressing wider agendas such as tackling poverty and social exclusion, promoting literacy, and improving health and well-being. The Committee's report also highlights some of the early impacts of the Welsh Governments' (2011) Strategic Framework document (*'Libraries Inspire 2012-2016'*) which re-inforced the role for libraries in areas such as digital inclusion, the provision of meeting places for community activities (Johnson and Griffis, 2014), information dissemination (e.g. regarding welfare entitlements, council services or advice regarding health promotion), the strategic delivery of careers advice, lifelong learning and information literacy support (Kinney, 2010; Museum, Libraries and Archives Council, 2010; Welsh Government, 2015). Previous studies have also highlighted the increased use of library facilities in times of recession when there is more demand for job-seeking activities, welfare advice and training (Anderson and Whalley, 2015; Child and Goulding, 2012).

The potential role of libraries in the provision of a wider range of digital services was reinforced at the UK level by a Carnegie Trust UK (2012) report and indeed are mirrored in other international contexts where libraries are at the forefront of promoting levels of digital literacy (for example, in the United States; Jaeger et al., 2012; Bertot et al., 2012; Luo and Park, 2013). Furthermore the key role libraries play in supporting the delivery of 'digital-by-default' welfare programs through for example the provision of Internet access in facilities within deprived communities is being recognised at a time when some libraries are struggling to maintain and

continue such provision (Anderson and Whalley, 2015). In the UK, providing a ‘*comprehensive and efficient library service*’ is a statutory requirement on local authorities under the 1964 Public Libraries and Museums Act (HMSO, 1964) but, as with other types of public service provision, is facing budgetary constraints. In view of such pressures, many library authorities have published public consultation documents which outline alternative models of library provision which have been proposed to improve the financial sustainability of library services (e.g. Ceredigion County Council, 2015). At present most services are provided through a system of community branch libraries and regional libraries, the latter of which typically offer a wider range of services. In addition to these ‘static’ sites, twelve of the twenty-two public library authorities in Wales (as of February 2016) offer a mobile library service to outlying communities which may include some housebound deliveries on-demand in more remote locations.

In order to help ensure national delivery standards are met the overall provision of library services are monitored by the Welsh Government through the implementation of Welsh Public Library Standards (WPLS), the fifth quality framework of which have recently been published (Welsh Government, 2014a). The use of such standards and current and future local authority plans for delivering public library services have been described in an *Expert Review of Public Libraries in Wales* report commissioned by the Welsh Government (2014b). The types of delivery models currently being considered by authorities faced with meeting reduced budgets whilst at the same time maintaining their statutory obligations include a rationalization of the number of directly managed library facilities; different types of community run or managed library services with varying degrees of professional library personnel input; services run by community trusts, social enterprise, mutual organisations, community councils or the private sector; reductions in opening hours; the co-location of library service points with other types of local authority services such as leisure, tourist information or community centres; sharing services with neighbouring local authorities; and, modifications of the locations and duration of opening of the mobile library service. For UK library authorities any such proposals must be accompanied by Equality Impact Assessments (EIAs) which aim to mitigate the social impacts of the proposed changes for different population age groups (such as those up to the age of 14 and those aged over 65), people living in deprived areas and, in Wales, those requiring library material through the medium of the Welsh language. The principal contribution of this paper involves a demonstration of how changes in the delivery of library services can potentially be modelled within such EIAs using spatial analytical techniques in order to inform

debates on the potential impacts of such changes for groups who lack the means to access library facilities (Preston and Rajé, 2007).

The techniques described here are based on principles derived from gravity models that account for variations in supply/demand relationships with distance to provide an interpretable measure of the amount of supply units (library attributes or characteristics) accessible per unit of demand. Drawing on a study of access to library services in one rural authority in Wales, we demonstrate the spatial accessibility manifestation of a public library reconfiguration programme that could be used to investigate the ‘distributional equity’ of provision as part of a wider study of those population groups most likely to use such services. Whilst there is a comparatively large body of research concerned with measuring access to public and private services in general, and library facilities in particular (as briefly reviewed in the next section), previous approaches have a number of limitations.

Firstly there is often little or no attempt to consider the interaction between supply-side characteristics of service points (such as total opening hours or other forms of ‘quality’ measures) and different facets of population demand that would permit the potential impact of changes in such characteristics to be examined following reconfiguration of services. Such factors invariably impact on the overall accessibility of services to local communities and can disproportionately penalize some user groups. The approach used in this study provides an intuitive supply-to-demand ratio based on travel time catchments rather than a methodologically crude count of (public library) facilities within administrative areas of residence. By considering an attribute of the library service before and after a potential re-configuration (in this case study, the minutes of opening of each facility), we retain the simplicity of a supply-to-demand ratio but also incorporate the proportion of the total service provision that is shared amongst potential population demand. The access score represents the relative share of total supply (i.e. minutes of opening of the library service) that a person in each population centre can reasonably access (given assumptions, or occasionally based upon empirical evidence, of how far people are prepared to travel to access the service) both before and after the proposed changes to the service. Secondly, the assumption that services are equally available to the population is debatable given the need to investigate the impact of distance-decay effects. The models described in this paper enable a decline in expected demand with increasing distance from service location to be incorporated into the calculations using various distance-decay functions.

This study demonstrates how these advanced models could be utilised by those charged with planning library services as well as for those groups concerned with monitoring the implications of changes in provision. We draw on service changes implemented within our study area during 2014 and 2015 in order to highlight the utility of such tools in assessing the implications of these changes in terms of the patterns of spatial accessibility prior to, and following, the re-organisation of library services. These changes are discussed in more detail in section 3 of the paper following a brief review of the types of Geographical Information System (GIS)-based approaches used to measure spatial variations in access to public library services in previous studies, as well as a description of the network-based GIS models implemented in the present study.

2. Monitoring changes in spatial accessibility to library services using Geographical Information Systems (GIS)

Whilst GIS functionalities in the form of basic mapping of facility locations are increasingly used to help inform decision-making processes surrounding the planning of public services, library authorities are not routinely using the types of network-based accessibility techniques developed in this paper as part of their impact assessments. This is despite the well-documented use of spatial approaches in the academic literature relating to the wider aspects of library provision including, for example, assessing initial siting decisions, analysis of branch locations, facilities management, monitoring trends in library utilisation and the delineation and analysis of library service areas (Bishop 2008; Bishop and Mandel, 2010; Donnelly, 2014; Hertel and Sprague, 2007; Koontz, 1997, 2007; Ottensmann, 1997; Sin, 2011). Previous studies have shown how GIS can be used to optimise sites for new library facilities (Lim and Park, 2015) or tailor the opening hours of facilities to the demographic characteristics of those living or working in specified catchment areas (Adkins and Sturges, 2004). In practice, approaches concerned with examining access to static libraries and mobile library stops have tended to be based on an analysis of market areas. For example, research in Northern Ireland used GIS to calculate the number of households living within two miles of a library or mobile library stop following a service re-organisation, with trends in provision for the new library service being compared to spatial patterns of deprivation, neighbourhood renewal areas (NRAs) and areas classified as either urban or rural (Libraries Northern Ireland/DCAL, 2014). Pertinent to the pressures facing library authorities in the UK and elsewhere to ensure equitable access to services, Koontz et al. (2009) have used the analytical capabilities of GIS to describe the socio-

economic characteristics of market areas impacted by permanent public library closures in the United States in the period 1999 to 2003. Their findings suggest that the users of such services in these areas tended to be poorer, less educated and more likely to be renters than homeowners. Their study also drew attention to the paucity of data on key aspects of public library provision, other than the physical location of the buildings hosting library facilities, which may also impact on the level of use of such services. Problems with collating longitudinal datasets on, for example, changes to opening hours, library book stock or the availability of computing facilities may also contribute to the comparative lack of studies concerned with using gravity models for examining the impacts of library service reconfigurations.

In order to provide a comparative level of service across Wales each library authority is charged with ensuring equitable geographical access to service points across their administrative areas. To meet such requirements one of the quality indicators in the fifth framework of standards of provision of library services (WPLSQI5) refers to the geographical availability of library service points (Welsh Government, 2014a). The guidance for the fifth framework suggests that such measures will be dependent on the population density within the library (local) authority. Thus, for authorities with a higher density of population (defined as 20 or more persons per hectare), the criteria to be met is that at least 95% of households live within 2 miles of a static library service point. For those with a density of between 1.1 and 19.9, the target is that at least 75% of the population is within 2.5 miles (or 10 minutes travelling time by public transport) of a static service point or within ¼ of a mile of a mobile library stop. Finally for the sparsest areas (defined as areas with 1.0 person or fewer per hectare), the criteria specifies at least 70% of the population should live within 3 miles (15 minutes travel time by public transport) of a library building or within a ¼ mile of a mobile library stop.

Given the explicit spatial nature of these criteria, GIS should be well placed to assess and monitor levels of existing (and future) provision (Talen and Anselin, 1998). Spatial accessibility can be measured using a number of approaches including measuring the distance/time taken to reach the nearest centre or a set number of facilities (*proximity* measures), a count of the number of service points per area or census tract (*container* or *density* measures), or the number of service points within a specified threshold time/distance (*cumulative opportunity* measures). GIS can also be used to incorporate other variables into an analysis of the distribution of facilities (Talen, 2003). For example, an early study concerned with using spatial approaches to examine the distributional impacts of library provision was

that of Cole and Gatrell (1986). In their study a gravity model was used to calculate access to library facilities weighted by straight-line distance from the population-weighted centroid of the smallest census area for which data were made available (enumeration districts at the time of the 1981 UK census). The choice of threshold distance (and form of the distance-decay parameter, β) were, in the absence of empirical data, acknowledged to be problematic but the maximum distance people were assumed to be prepared to travel was set at 2km and $\beta = 1.0$). Library 'attractiveness' was gauged by the level of book stock and an access score calculated and then compared to an easier to compute and conceptually familiar measure based on distance to the nearest library. Proposals for changes in library provision (for example the construction of a new branch library) were analysed with consideration to the characteristics of the local populations likely to be impacted by changes in provision. Furthermore census data were used to evaluate the effectiveness of mobile library service provision in serving for example those over retirement age. The authors suggest that such measures could be further refined by conducting sensitivity analysis on the choice of critical distance and distance-decay parameters, by replacing Euclidean distances with network-based measures and by including different library 'attractiveness' measures (such as opening times, stock levels, physical access arrangements, etc.).

Of particular relevance to the aims of the present study, Ottensmann (1994, 1995) demonstrated how gravity models can be used to predict library utilisation following a service reconfiguration of branch libraries in Indianapolis using supply-side data, including levels of book stocks. Analysis suggests a significant correlation between the nearest distance to a branch library and median family income at the census tract level, with people living in the poorest areas on this measure having shorter distances to travel to the nearest branch library. However, there are trade-offs between the quantity of resources available at library sites and accessibility such that trends were reversed for the relationship between the distributions of book stock located at libraries and the income variable. This, Ottensmann suggests, will have different consequences for areas with contrasting socio-economic circumstances; it was found for example that those branches serving more affluent census tracts maintained a correspondingly larger stock. This in turn suggests that attempts to examine equity in the provision of existing (and projected) levels of library services need to simultaneously account for the distances needed to access such facilities *as well as* the services provided. A further refinement, included in the analysis presented in the current study, is a 'competition' element that can be introduced into network

based models to account for the fact that some residents have a choice of library facilities to use within specified distance or time thresholds.

Findings from previous studies, backed up by anecdotal evidence in our study area, suggests that not all those registered with a library are using the facility that is closest to their home; either because users are potentially using services closer to their workplace or educational establishment or, alternatively, that the wider range of services and longer hours at main library sites are attracting customers from further afield (e.g. Ottensmann, 1997; Park, 2012a). This is further enabled through users registered in their ‘home’ library authority area drawing on library services in adjoining authorities within Wales. We need, therefore, to be sensitive to the ‘cross-boundary’ use of facilities. Relatedly, one approach that has been used to assess the impacts for sampled individual’s accessibility has involved the use of time-space measures to examine the implications of the proposed rescheduling of opening hours of libraries (Delafontaine et al., 2011). Such techniques show real potential in providing a more realistic assessment of the impacts of such factors on changing access to library facilities. However, the efforts needed to create library visitor activity/travel diaries as well as library scheduling data sets required of such measures means that these methods have not, as yet, been routinely adopted.

The present study builds on previous approaches by advocating the use of ‘enhanced two step floating catchment area techniques’ (E2SFCA) which consider the interaction between supply-side variables used to proxy for the ‘attractiveness’ of library facilities in relation to the potential demand for services within a user-defined threshold distance or time (usually represented from a centroid of census tract), whilst also accounting for the potential impact of distance (usually modelled by a distance-weighting parameter). Fuller details of the technique are presented elsewhere (e.g. Luo and Wang, 2003) but essentially the model permits the interactions between consumers and service providers to be analysed within user-specified service areas based on either travel time or distance. It also enables small area estimates of accessibility to be calculated for further analysis. Further enhancements to the model such as the incorporation of distance decay weightings within catchment areas have also been proposed since the introduction of the first generation of FCA models (Luo and Qi, 2009, McGrail and Humphreys, 2009; Fransen et al., 2015). FCA models have been used a range of application areas such as measuring access to sporting opportunities (Cutumisu and Spence, 2012), health

care facilities (Dai, 2010; Ngui and Apparicio, 2011) and transport facilities (Langford et al., 2012).

Higgs et al. (2013) have drawn attention to the potential advantages of the FCA approach to analyse small area variations in accessibility to library facilities using data on library facility locations and Census-derived population totals. However, in common with other studies to date that have used FCA approaches, there is limited consideration of how historic patterns of library provision and associated service reconfigurations could be analysed. Furthermore, their study does not consider how the nature of library services offered in various locations (i.e. characteristics such as opening hours, staffing levels, book stock, etc.) could be incorporated into the analysis of accessibility levels. Part of the reason cited for this critical lacuna concerns the lack of historical and contemporary data sources on levels of provision, and the paucity of nationally consistent sources of information on the types of services offered within libraries. This has largely limited studies to localised attempts to model the impact of changes to one or two library service points. However, other studies have demonstrated how supply-side parameters available in other service sectors can be employed in accessibility calculations as part of FCA approaches. These include, for example, the number of hospital beds at a health centre, the number of jobs at a particular location, and other so-called measures of service ‘quality’.

The aim of this research is to demonstrate how one specific variable, namely the opening hours of libraries prior to and following a proposed reconfiguration of service provision in one library authority area, can be used with network-based gravity models to generate maps of spatial accessibility at the census tract level. These spatial accessibility surfaces can then be compared to the distribution of demographic groups including the young, un(der)employed and elderly – often considered some of the major potential users of library services – in on-going impact assessment exercises. FCA models allow us to identify geographic variations in accessibility and comment on possible disparities in provision and should have wider resonance for service providers monitoring the impact of alternative delivery models in the face of austerity driven measures. The following section details the changes in static and mobile library provision being implemented in the case study authority under investigation in 2014 and 2015 which we draw on to illustrate the potential of FCA techniques for those planning changes to library services or with monitoring their implications for local communities.

3. Measuring changing access to library provision: a case study of Pembrokeshire

3.1 Changes in library services in the county

There were over half a million visits to libraries in Pembrokeshire in 2013/14 and libraries continue to generate the types of wider economic and social benefits highlighted previously. However, as is the case with other library authorities in Wales, recent local government financial settlements have meant that library service provision is under continual scrutiny. This has resulted in on-going discussions and public engagement processes geared to reviewing the future of libraries in Pembrokeshire in relation to community needs and the potential co-location of local authority services. Whilst many of the problems of service provision are shared across authorities, there are also issues pertaining to Pembrokeshire as a predominately rural region: specifically, the need to maintain a service and communications infrastructure for a geographically dispersed population with higher proportions of retired people who are often overly dependent on a declining public transport service to access facilities (Pembrokeshire County Council, 2015).

Many of the issues concerning the operation of library services are mirrored in other rural areas of the UK where, typically, the distances to access such services are greater, fewer services exist with which to co-locate library services and there are lower levels of footfall which, in turn, suggest that changes to library services may have wider ramifications for rural communities (OPM, 2014). Rural communities, for example, often maintain lower levels of broadband access, limiting the capacity of electronic resources to overcome a limited physical service infrastructure. This convergence of pressures is well documented in the literature. Velaga and colleagues (2012; p. 102), for example, note that “constraints in rural transport infrastructure and services are often compounded by limitations in the development and resilience of technological infrastructures” (2012, p. 102). In this context, there is a significant disparity in provision in rural communities in comparison to urban locations. With a large proportion of Pembrokeshire residents living in rural and ‘deep’ rural locations, it may be reasonable to assume that some of these residents are, on the whole, more reliant on IT services provided by their local library for services such as welfare provision and e-learning.

The changes being studied in this article are based on a recent reconfiguration exercise which took place within the county between October 2014 and April 2015. As of April 2015 library

services in Pembrokeshire were delivered through a network of twelve ‘static’ libraries (*Full-time*: Fishguard, Haverfordwest, Milford Haven, Pembroke Dock, Tenby; *Part-time*: Pembroke, Saundersfoot, Crymych, Narberth, Newport, Neyland and St Davids) and one mobile library service serving approximately 60 stops located in predominantly rural areas of the county (Figure 1). In November 2014, the authority undertook a month-long consultation exercise concerned with gauging opinions on proposed changes to the opening hours of the static library services. These proposals were guided by an analysis of the times of peak usage at each site and involved a proposed reduction in late night opening times, some afternoon closures (guided in places by seasonal demand) and some lunchtime closures between certain hours. Subsequent reductions to the opening hours, stemming from budgetary pressures, came into effect on 1st April 2015 following this consultation period. Following a separate Mobile Service Review conducted in early 2014, the authority also made changes in October 2014 to the timetabling and stops involved in the provision of the mobile service (Pembrokeshire County Council, 2014). These were primarily aimed at reducing the total number of stops made but also involved longer visits to each stop (Figure 1; Panel B). The review specifically targeted those remote areas of the county where residents were unable to attend static services due to lack of access to private or public transport. Prior to this, the service consisted of one van visiting each stop once every three weeks and two smaller vans visiting individual customers (details of the latter have not been made available to the researchers for disclosure reasons). Following consultation the frequency of mobile services were reduced to once every four weeks and the new service comprises a single vehicle covering 8 routes over this four week period. Further changes from November 2014 included the introduction of a new ‘Library at Home’ service for those (potentially vulnerable and often housebound) individuals that are unable to access static or mobile library facilities.

[FIGURE ONE INSERTED ABOUT HERE]

Models based on the E2SFCA technique promoted in this paper enable changes in the opening hours of library services to be readily incorporated into the calculation of accessibility. Our aim is to compare the scores of census tracts (so-called ‘output areas’ averaging approximately 300 people) before the changes to the mobile service (prior to Oct 2014) and changes to the static service (implemented by the authority in April 2015) with the distribution of access scores after April 2015 by which time changes to both services had been implemented. In both cases the supply-side variable calculated was the monthly minutes of openings/availability of

the combination of static and mobile services (aggregated for the output areas in existence during the 2011 UK Census of Population). In order to reflect potential access to static library sites outside the county, facilities close to the border but in the neighbouring authorities of Carmarthenshire and Ceredigion were also included in the analysis. From September 2009 membership of a local library service permitted customers to use or join other public library services in other authority areas (Davies, 2010). There could also be cases of individuals using mobile services in adjoining counties, but these are likely to be fewer in number. Such flows could be incorporated into the models if available, but that was not the case in this instance.

With regard to service catchments, in order to comply with the availability criteria specified in the Welsh Governments' standards of provision for library service points (Welsh Government, 2014a), thresholds in the models were initially set to 3 miles for a static service point and ¼ mile for a mobile stop. However, these can be easily varied if empirical evidence is available on the actual distances people travel to utilise either types of services. The Ordnance Surveys' Integrated Transport Network (ITN) layer is used to calculate road network travel distance and time (Ordnance Survey, 2015) using the ArcGIS™ version 10.2 Network Analyst extension with demand being measured from population weighted centroids for output areas. Finally, to calculate the FCA accessibility scores bespoke software (an ArcGIS Add-in) is used which incorporates a distance-decay parameter within the user specified catchment threshold. This acknowledges that potential demand for library services is likely to decline with distance. In this example, in the absence of any empirical data on the actual use of services in Wales, a linear decay option is adopted which simply tapers off uniformly to zero at the threshold point. Again, alternative distance-decay models could be readily substituted if suitable data became available on actual utilisation patterns of services within the county. Essentially the two steps involved firstly calculate the 'minutes of library provision – to – population' ratio of each facility by summing the total population of all output areas lying within travel time catchments. The second step employs these same thresholds around each centroid to identify all the library service static and mobile service points deemed within reach. An average rate of availability of library services within the specified thresholds for each facility can then be calculated.

3.2 Results from Accessibility Models of library provision

3.2.1 Spatial impacts of changes to the static library service

With a reduction in the total number of opening hours provided at the static library sites there is an inevitable reduction in the total service provision, and thus a commensurate overall lowering of FCA accessibility scores. In particular there is a ‘constriction’ in access scores around those libraries where the opening hours were reduced (such as those based in Haverfordwest, Narberth and Crymych). Within this overall decline in accessibility, the spatial patterns in FCA scores enables planners to explore the extent to which accessibility loss is spatially uniform. There will be other parts of the authority, for example, where broadly similar patterns in access scores for static services are seen both before and after the changes in opening hours. Given that both the demand population and the service supply points are spatially unevenly distributed, that the reductions made to service provision amongst the supply points is non-uniform, and that the demand and supply points are connected via a complex road network infrastructure, it is almost certain that the decline in service experienced by the population will be to some extent spatially inequitable. Once such patterns are determined we can consider such inequalities relative to the distribution of other socioeconomic characteristics of potential interest, such as population age profiles, deprivation indicators, ethnicity, and so on.

One way to look at such inequalities is to study those areas that have seen changes to their overall service provision measure - in this instance reported by ‘monthly minutes of open time’ – thus the FCA scores represent a measure of the available “minutes of service per person”. Based on a total residential population (at the time of the 2011 Census) of 116,341, and a total static service provision prior to reconfiguration of 1712 hours and 1433 hours after reconfiguration, this equates to 0.883 minutes of open time per person before reconfiguration and 0.739 minutes after reconfiguration. Expressed in terms of service accessibility change there was a loss of 0.144 minutes of open time per person, or a reduction in service provision to 83% of the pre-configuration change level. Using these ‘global’ figures we are then able to identify areas of the county that have been relatively well shielded from changes and those that are more adversely impacted. Figure 2 shows the map of FCA scores before service reconfiguration, illustrating how the global figure of 0.883 minutes per person already shows considerable spatial variation locally. A total of 111 output areas (of the 399 total) record no service provision at all using the threshold times specified, leaving those that do record a score

to average 1.21 minutes. The highest FCA score recorded was 9.922 minutes per person, but the frequency distribution shows that actually very few output areas record a score above 3.0 minutes per person (Figure 3), and that overall there is a mildly positive skew with a strong modal tendency around the global average value (0.883).

[FIGURES TWO AND THREE INSERTED ABOUT HERE]

Whereas global service provision is 83% of the pre-configuration level, we can expect this figure to vary spatially and it is that which is of primary interest to those examining the spatial impacts of changes in provision. Excluding from this analysis the 111 output areas that showed no change by virtue of having a zero FCA score both before and after reconfiguration, there were a further 20 output areas that reported no change, but in this instance by having identical non-zero FCA scores. This situation represents the ‘best possible’ outcome, because no FCA score can increase under a regime where the service provision is reduced while the demand population remains unchanged. In effect, these twenty output areas are ‘untouched’ by the effects of the global service reduction. Any output area with a post-change score that is greater than 83% of its original score has also ‘beaten the odds’ to an extent. In this situation, whilst their service provision has reduced, they are less severely affected than the global average. Likewise, output areas with a post-change score less than 83% of their original score are relatively disadvantaged compared to the ‘global’ average for the county. The lowest such score was 71.9% and the statistical distribution of scores is shown in Figure 4. Because FCA models map the distribution of a finite service volume, there is a balance here such that if some output areas do better than expected, others must do worse to compensate. Potentially more interesting therefore is a map of the relative ‘winners’ (those with a reduction of up to 17%) and ‘losers’ (those with a reduction of more than 17%) that helps us to seek comparisons with the distribution of other social-economic indicators (Figure 5).

[FIGURES FOUR AND FIVE INSERTED ABOUT HERE]

3.2.2 Spatial impacts of changes to the mobile library service

A similar approach was used to measure the impact of changes to mobile library services in the county. This reported a total supply-side provision of 42.4 hours prior to reconfiguration, and 26 hours post reconfiguration, or 0.022 minutes per person, and 0.013 minutes per person respectively. The reconfiguration resulted in a service reduction to 61.25% of the original

provision. After reconfiguration there were fewer stops, but with a longer time of availability for those that remained, with the specific intention of addressing areas with poor access to static sites. FCA outcomes following reconfiguration are slightly more complex than before. As with the static sites, some output areas report no access to a service before or after reconfiguration. Others show a decline in service provision, including some that decline to the point of having ‘no service’ at all. However, some output areas record an FCA score post-reconfiguration when they had ‘no service’ status before. This is all possible because some new service provision points were introduced while other previous mobile sites were axed. Thus we can get dramatically different FCA ratings for the mobile service (Figure 6). In summary, some output areas gained access to a service having had no prior provision, some improved on their FCA score indicating a better level of provision, some lowered their FCA score indicating a worsening level of provision, some lost access to a service having had prior provision, and some had no access to a service before or after reconfiguration. The twelve Output Areas shown to have acquired mobile service access (identified with the cross-hatch symbol) received a score close to the global average for those Output Areas with a pre-existing mobile service. The thirteen Output Areas with improved access (identified with the simple hatch symbol) saw an average gain of 50% over their pre-reconfiguration score. The map reveals notable increases in scores for those output areas in the north east of the county that had previously been characterized by more limited service provision. In contrast, other localities have witnessed a decline; including for example Haverfordwest, Milford Haven and Neyland where static libraries have been retained at the cost of a reduced mobile service provision in the immediate surrounding areas. Similarly, the area around Saundersfoot and Tenby has witnessed a loss of mobile service provision impacting on FCA scores in the south-east of the county.

[FIGURE SIX INSERTED ABOUT HERE]

4. Discussion

The tools developed during the course of this study demonstrate how detailed analysis of changes in accessibility can be used to better understand the socio-spatial implications of changes in services at the community level that may be masked by overall ‘headline’ figures for library authority areas. The results of such analyses should feed into the equality impact assessments that need to be conducted in order to understand how projected changes in the delivery models compare to spatial patterns of projected needs for the service based on the

principal users of different types of library services (Hawkins et al., 2001). Wales has been spared the level of losses of libraries experienced in other countries over recent years (for example in comparison to the 55% decline in the numbers of libraries in Denmark between 1988 and 2011; Svendsen, 2013). Nevertheless, as elsewhere, current budget cuts mean that library authorities will be under increasing pressure to maintain existing levels of service provision at a time of staff reductions and increasing demand for services. The need to plug the gaps in service provision may be even more acute given the pressures involved in maintaining existing levels of provision in rural library authorities such as Pembrokeshire. As library authorities consider alternative models of service delivery, there is an increasing likelihood that charities, social enterprises, community organisations and private sector organisations will be involved in the management and running of library facilities. This, together with the move to networks of co-located community hubs, could lead to inconsistencies in the level of provision as different authorities tailor their networks of public libraries to their particular community needs or financial resources (Welsh Government, 2015). Evidence from areas where there has been an increasing number of volunteers involved in library provision in the UK suggests that this may impact on the range and quality of core services once offered by professional librarians (Arts Council England, 2013; Casselden et al., 2015). In this study we have used the number of minutes of provision of services as a library-level characteristic, but accessibility scores could be compared for other supply-side indicators (such as staffing levels, availability of computer-based training sessions, stocks of books or ICT provision, etc.). For example, Mladenka and Hill (1977) used alternative supply-side parameters including total staff rolls and levels of staff with professional qualifications to investigate variations in provision. Going forward, the types of tools described in the present study have potential to be used by those charged with developing models of service delivery to plan the provision of, for example, co-located community hubs and the types of services offered at each facility.

The intention of this study is to highlight spatial patterns in accessibility to library facilities prior to, and following, changes in service delivery within a ‘typical’ library authority in the UK. There are a number of limitations to the approach taken here; addressing these shortcomings, we argue, could form the basis of further research efforts in this area. For example, we have not to date considered various aspects of mobility that otherwise impact on personal accessibility in the context of users accessing library services. These include car ownership, public transport availability and timetable information, access to community transport or lifts from neighbours. Such data, if available, could be used in relation to the

opening times of library services in order to investigate the possibility of attending local libraries for those unable to access services via private means of transport. Recent research has demonstrated how public transport metrics can be incorporated into FCA analysis in the context of health services using multi-modal accessibility approaches (Mao and Nekorchuk, 2013; Langford et al., 2016). However, to our knowledge no research has been conducted into the use of such approaches in the context of library availability.

In addition, library visits are increasingly linked to a wider range of educational and social activities than addressed in this paper. For example, previous studies have highlighted that including access from workplace or schools should also be included in GIS-based approaches (Park 2012b). While we have used ‘official’ thresholds identified in Welsh Government guidance notes to define the immediate catchments of potential users, there is no nationally consistent threshold used to delineate how far people are actually travelling to access library services. A review of previous GIS studies largely conducted in the United States found that straight-line distances of between 1 and 2 miles (1.6 – 3.2km) have been used to define library service areas based on circular buffers (Donnelly, 2014). These in turn lent heavily on earlier empirical evidence from studies conducted in the late 1970s/early 1980s on how utilisation of library facilities varied with distance (Palmer, 1981). Donnelly (2015) in his study of regional variations in average population-weighted minimum distances to libraries in the United States provided evidence of the appropriateness of the use of two mile buffers in such studies whilst drawing attention to the importance of local circumstances in delineating service areas. However, such studies rarely account for the actual library used by local communities, the characteristics of library services offered at each site or the type of library service being accessed (e.g. book lending, utilisation of digital services, etc.) which acknowledges that people are prepared to travel greater distances to access libraries with specialised collections or facilities. A strength of our approach is the inclusion of alternative forms of provision in the form of mobile library services. Whilst it is acknowledged that mobile services lack all the facilities that are available at static sites they nevertheless represent an important form of provision particularly for those living in deep rural areas. This is certainly the case in rural counties such as Pembrokeshire which are particularly vulnerable to the consequences of budgetary and service cuts at an individual and community level.

The study has essentially compared associations at two cross-sections in time in order to demonstrate how GIS can be used to monitor the spatial implications of changes in library

provision. The library service in the county has undergone further restructuring including an increase in its aggregate opening hours in response to public concerns since the plans described in the paper. As elsewhere in the UK, there is a constantly changing landscape of provision in response to budgetary pressures and service demands. Although the circumstances in this authority may be different to one serving a predominantly urban population for example, the tools developed here have wider applicability and relevance for other types of scenarios or changes in delivery models for a range of different services. However, collating the information required to provide a detailed picture of the implications of changing provision in library services using the types of models described in this study is far from trivial. There are wide variations in the quality of statistics available both across UK library authorities and indeed in wider international contexts. By drawing attention to the potential for incorporating detailed attribute information on the types of services being offered within public libraries and other characteristics of provision (such as opening hours), the aim here is to highlight the importance of the underlying data requirements and the need for consistent approaches to assemble core datasets that permit such spatial analytical tools to be fully utilised.

Whilst the variations in FCA accessibility scores have pinpointed issues that may be relevant for those living within particular census tracts (output areas), more detailed analysis is required to begin to understand the implications for individual users of the library service. Individuals may choose to move to areas where accessibility is perceived to be problematic for a whole host of alternative motivations or, depending on their individual circumstances/preferences, may have voluntarily accepted lower levels of accessibility to a wide range of public services. Finally acknowledging that this study used census output areas, the smallest reported census unit in the UK with a target population of 300 persons, and despite accounting for cross boundary flows and moving away from simple aggregated areas within the FCA models, it is possible that the use of other neighbourhood definitions could impact on findings when analysing potential associations with socio-economic data. Previous studies have drawn attention to the importance of choice of spatial unit on the degree of socio-spatial inequality observed by incorporating sensitivity analysis using alternative spatial scales (e.g. Irwin, 2007).

6. Conclusions

As provision has evolved in the last fifty years, public libraries have become central to promoting computer literacy, tackling poverty and improving skills and addressing health and

social well-being agendas at the local community level. Internationally, the use of library facilities has also been seen to contribute to levels of social capital by adding to the social impacts of existing community-based networks (Griffis and Johnson, 2014), by reducing social isolation and fostering inclusion (Johnson, 2010; Stilwell, 2016), by promoting collaboration between other types of service providers (Svendsen, 2013) or through interacting with trends in structural or social patterns of neighbourhoods (Gong et al., 2008). In such circumstances libraries are often rooted within communities that are protective of services perceived to be integral to the vitality of their local areas. Such concerns are evident in high profile ‘Save Our Library’ campaigns that have been launched following proposals regarding changes planned by some library authorities throughout Wales. The Welsh Government is committed to working with communities “to protect local facilities that bring people together, including pubs, libraries, museums, arts centres and leisure centres.” (Welsh Government, 2016b; p. 13). At the same time alternative delivery models are being developed by local authorities who retain statutory responsibility for running library services. To date there has been little research that has explored the consequences of implementing such delivery models for changes to geographical accessibility that consider the combined impact of different forms of library service provision.

Where GIS has been used by library authorities, this has largely been confined to planning the provision of services in order to ensure spatial access standards are met. In the case of libraries this has typically involved mapping the distribution of users of different library services, analysing the average distances needed to access such services and examining service areas in relation to the socio-economic characteristics of local populations. The types of tools described in this study, based on floating catchment area models, builds on the earlier research based on gravity models developed by Ottensmann (1995) amongst others by including supply-side parameters such as the opening hours/minutes for each library service point whilst permitting all libraries in the threshold catchment to ‘compete’ for consumers. This overcomes limitations of calculating supply/demand ratios for often geographically large administrative areas by instead permitting cross-boundary flows where people are accessing libraries in adjacent areas. Findings from the present study demonstrate that network-based accessibility tools have the potential to simultaneously model the impacts of changes to the geography of library service delivery (such as closures programs) as well as including such supply-side characteristics in accessibility calculations. In such circumstances it will be important to monitor geographic disparities in the quality of provision following service adjustments and reconfigurations in

parallel with the types of equality impact assessments that have to be conducted by library authorities. Detailed mapping and spatial modelling approaches, as highlighted in this case study, have the potential to meet such aims by helping to effectively implement plans relating to the equitable provision of services in relation to service needs whilst also contributing to wider agendas concerning democratic accountability in service delivery decision-making processes. Such trends need to be seen in the context of wider debates surrounding the design and delivery of a wider range local government functions, the governance arrangements guiding such provision and potential re-organisation of local government that stress not only the role of geographical proximity but encompass regional and national initiatives as potential models of delivery of (library) services (Welsh Government, 2011, 2014c).

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8. Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article

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CAPTIONS FOR FIGURES

Figure 1: Distribution of Static and Mobile Library services in Pembrokeshire (**Panel A:** Before April 2015; **Panel B:** As of April 2015)

Figure 2: Before reconfiguration accessibility to libraries

Figure 3: Distribution of FCA scores by Output Areas before reconfiguration

Figure 4: Distribution of FCA scores by Output Areas after reconfiguration

Figure 5: Changes in Static Library service Accessibility Post Reconfiguration

Figure 6: Changes in Mobile Library Service Accessibility Post Reconfiguration

Figure 1: Distribution of Static and Mobile Library services in Pembrokeshire (**Panel A:** Before April 2015; **Panel B:** As of April 2015)

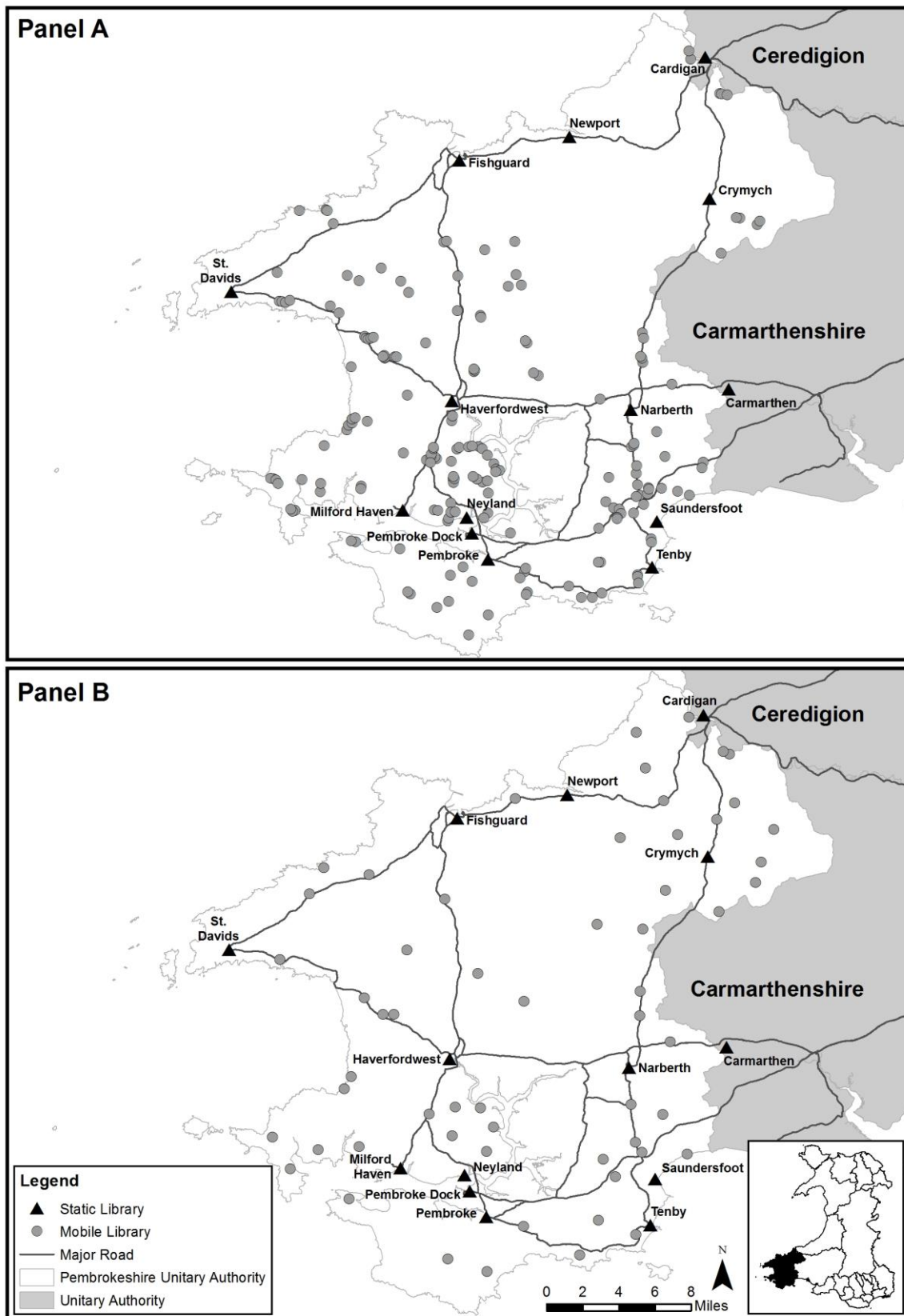


Figure 2: Before reconfiguration accessibility to libraries

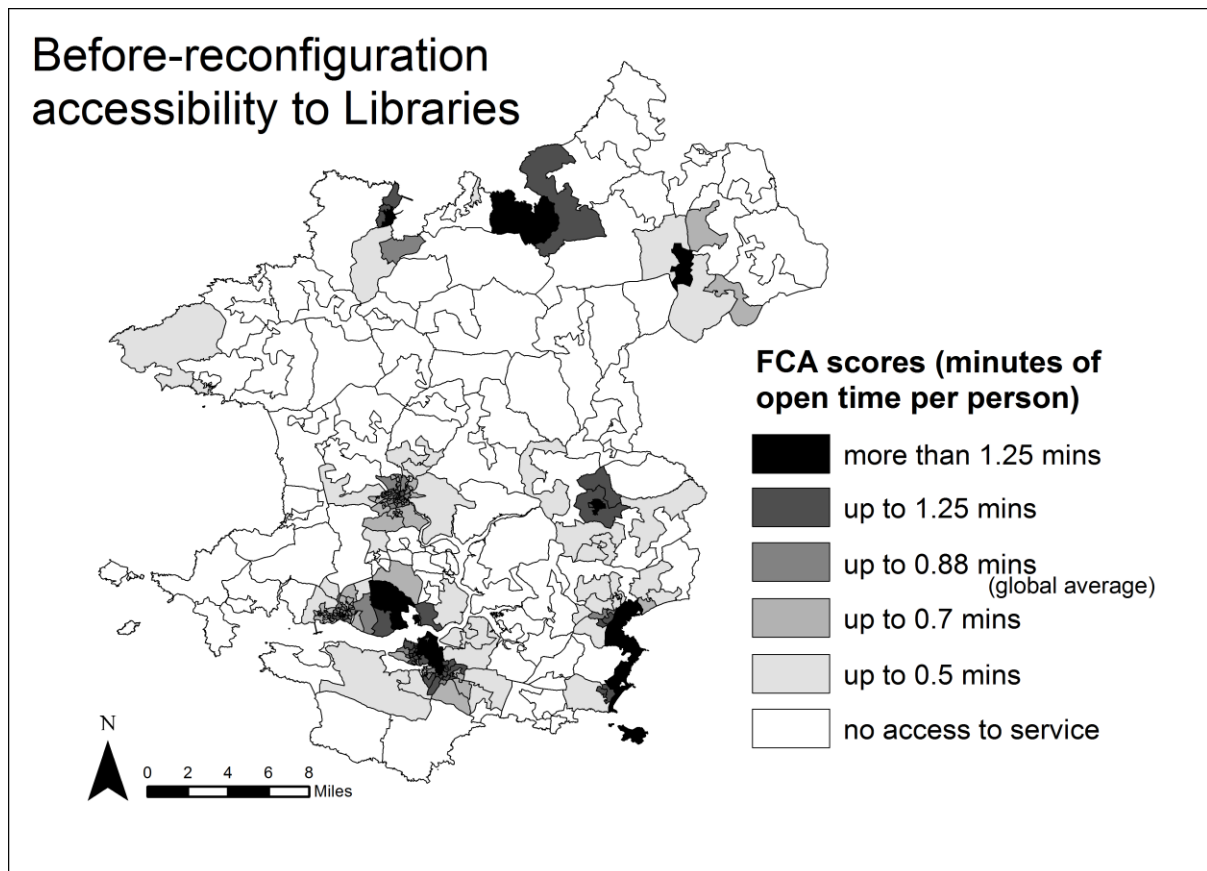


Figure 3: Distribution of FCA scores by Output Areas before reconfiguration

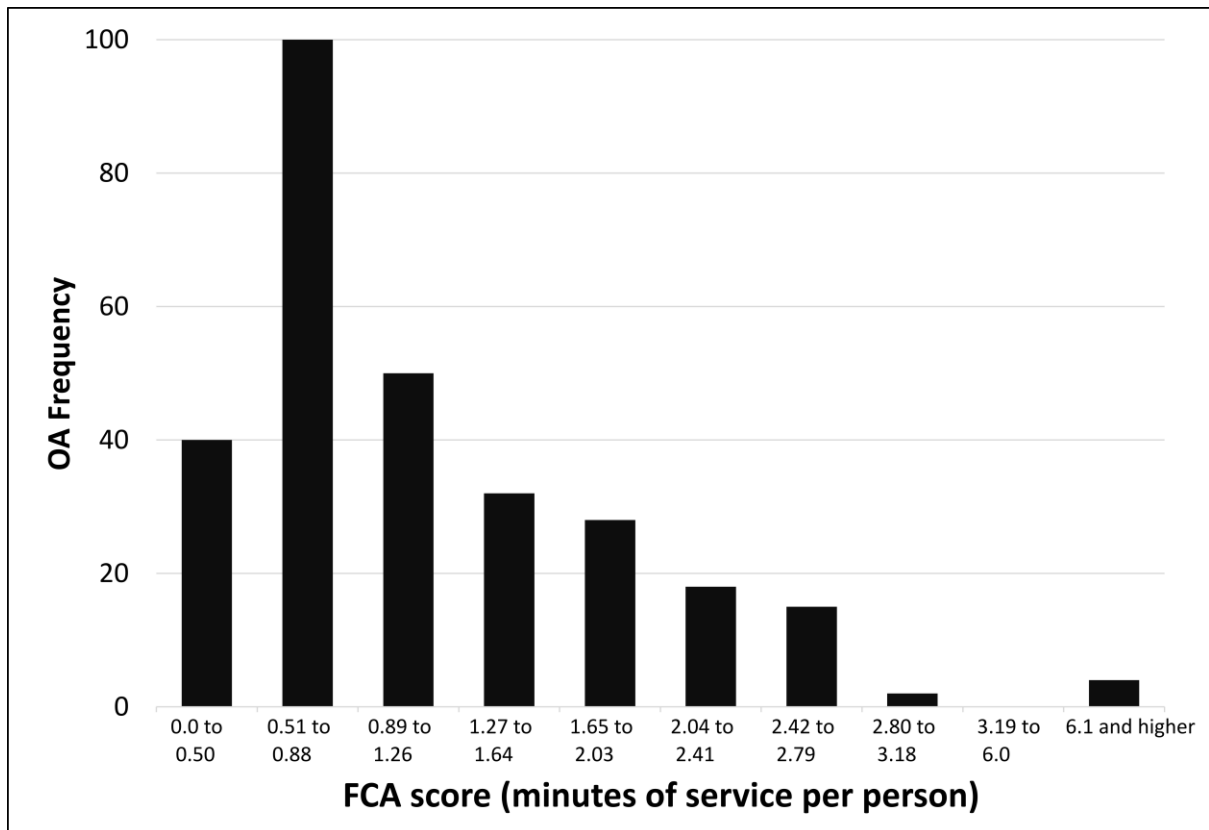


Figure 4: Distribution of FCA scores by Output Areas after reconfiguration

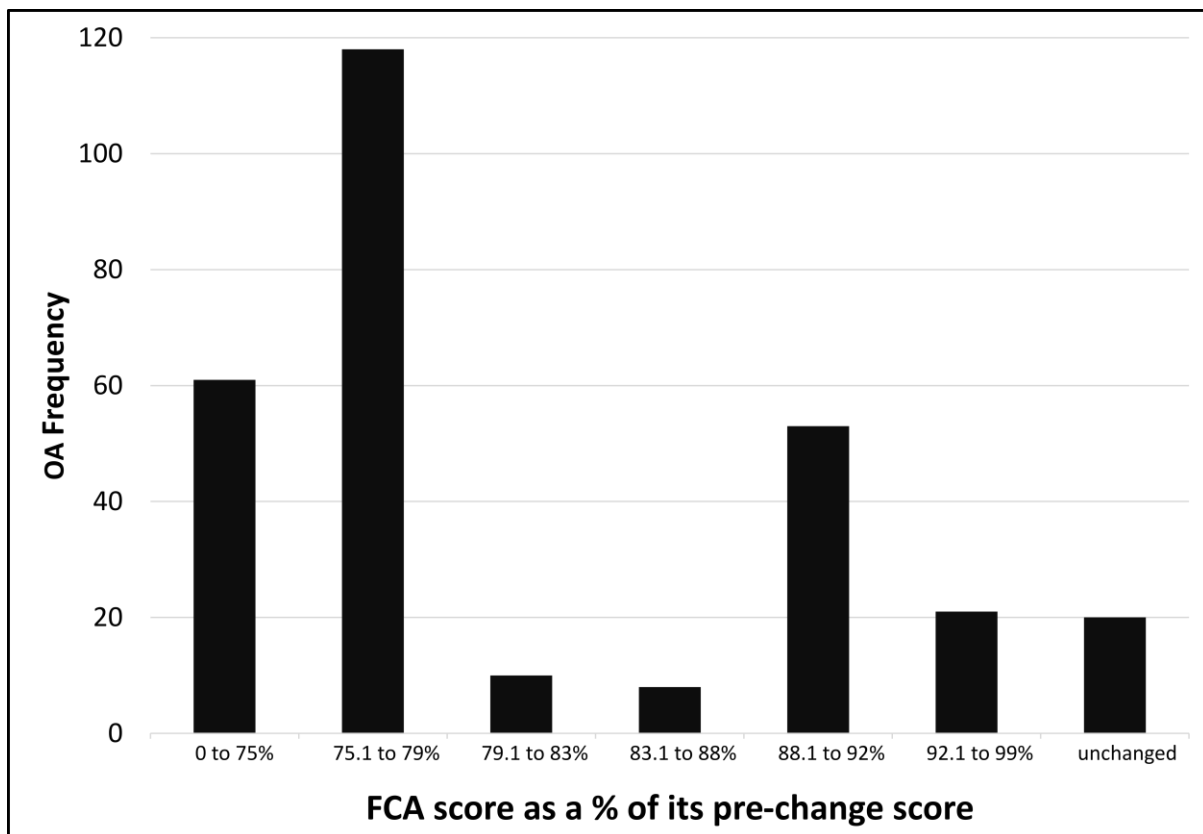


Figure 5: Changes in Static Library Service Accessibility Post Reconfiguration

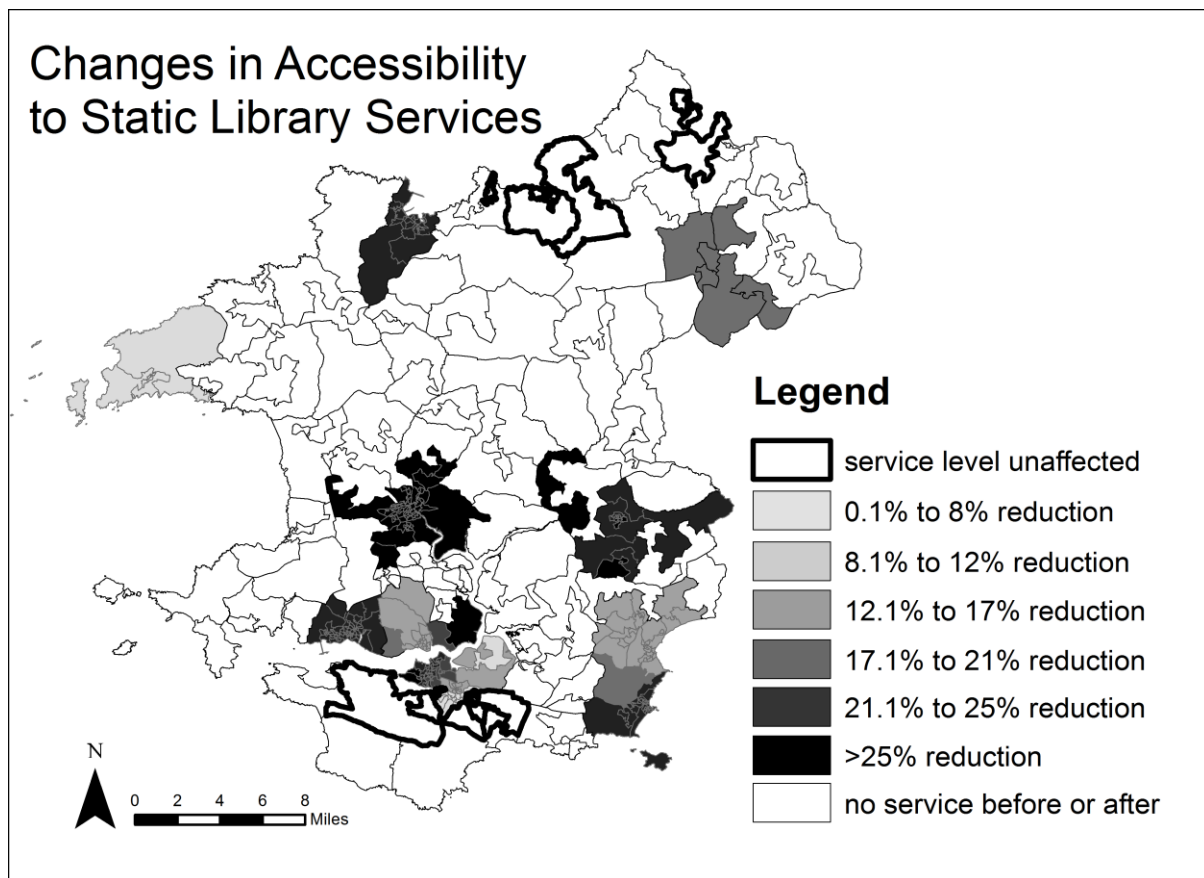


Figure 6: Changes in Mobile Library Service Accessibility Post Reconfiguration

